SOIL AND ECOLOGICAL FEATURES OF *HEXALECTRIS* (ORCHIDACEAE) SITES

Annie B. Collins

Biology Department
University of Dallas
1845 E. Northgate Drive
Irving, Texas 75062, U.S.A.

James E. Varnum

14524 Tamerisk lane
Farmers Branch, Texas 75234, U.S.A.

Margaret Brown-Marsden[1]

Biology Department
University of Dallas
1845 E. Northgate Drive
Irving, Texas 75062, U.S.A.

ABSTRACT

Soil and ecological features of the orchid genus *Hexalectris* were examined to obtain a more accurate description of the factors influencing its distribution and to direct future conservation efforts. Data on canopy and ground cover, tree species diversity, and soil series were obtained for *Hexalectris* in Dallas County, and overlaid with historic data on *Hexalectris* in Texas. We determined that *Hexalectris* does associate with oak and juniper, but the amount of cover at *Hexalectris* sites did not exceed 60%. Ground cover, tree species diversity, and percent oak/juniper did not differ between sites with and without *Hexalectris*. The soil series associated with *Hexalectris* in this region were Eddy-Brackett entisols of 8–20% slope. Soil type was an accurate predictor of areas in which *Hexalectris* could be found. *Hexalectris* appear to be strongly dependent on soil series, a factor which can aid in predicting areas in which *Hexalectris* is likely to be found but has not yet been located, as well as in conservation of this less well-studied genus.

RESUMEN

Se examinaron las características ecológicas y del suelo de la especie de orquídea *Hexalectris* para obtener una descripción más precisa de los factores que influyen su distribución y para futuros esfuerzos de conservación. Se obtuvieron datos de la canopia y el recubrimiento, diversidad de especies arbóreas, y series de suelo de *Hexalectris* en el condado de Dallas, y sobrepuestos con datos históricos sobre *Hexalectris* en Texas. Determinamos que *Hexalectris* sí se asocia con roble y enebro, pero la cantidad de los sitios de *Hexalectris* no excedieron el 60% y además el área cubierta, la diversidad de especies arbóreas, y el porcentaje roble/enebro no cambió entre sitios observados con o sin *Hexalectris*. Las series del suelo asociadas a *Hexalectris* en esta región eran suelo Eddy-Brackett con 8 al 20 por ciento de inclinación. El tipo de suelo fue un indicador preciso para poder predecir el área en que se encontraría *Hexalectris*. *Hexalectris* parece depender fuertemente en la clase de suelos, un factor que puede ayudar a predecir áreas en las que pueda encontrarse *Hexalectris* pero todavía no pueden ser descritas, al igual que la conservación de este género mucho menos estudiado.

[1] Author to whom correspondence should be addressed.

INTRODUCTION

Most orchids begin life by forming a mycorrhizal relationship, as seed germination is dependent on a mycorrhizal association to supply the seedling with carbon during its early stages; a relationship known as myco-heterotrophy (Dressler 1981; Leake 1994; Smith & Read 1997). Ultimately, approximately 80% of orchids switch from the myco-heterotrophic lifestyle to one in which carbon exchange occurs in the opposite direction, from orchid to fungus (Atwood 1986). Only 20% of orchid species maintain this symbiosis throughout their lifetime, which can evolve to a high degree of mycorrhizal specialization (Rasmussen 1995; Taylor et al. 2002). Within the recognized orchid subfamilies, the appearance of myco-heterotrophic species is nearly ubiquitous, and these kinds of orchids can be found within all tribes of the Orchidaceae (Dressler & Dodson 1960; Chase et al. 2003). Although recent work has sought to understand the nature of the mycorrhizal associations for orchids and how they relate to orchid taxonomy (Zelmer et al. 1996), less is known about how myco-heterotrophy is related to geographic distribution. It is thought that a high degree of specificity between orchid and fungus may have broader conservation implications, as protection of endangered myco-heterotrophic forms requires both the maintenance of the orchid itself as well as its associated fungus (Taylor et al. 2003). Because these orchids have a relatively low ability to withstand transplantation from the wild (Liggio 1999), determining the specific features found in the habitat of myco-heterotrophic orchids can provide a key to understanding their geographic distribution, and ultimately aid their conservation worldwide.

Corallorrhiza Gagnebin and *Hexalectris* Rafinesque are the only two genera of myco-heterotrophic orchid that occur in Texas. Members of both genera are commonly called "coral root" orchids, due to the presence of anthocyanin in the rhizome, stalk, and flowers (Liggio 1999), although the genera differ in their broader appearance, habitat, and distribution. *Corallorrhiza* includes ten species, of which nine are native to North and Central America (Freudenstein 1997). The genus *Corallorrhiza* is found within all the lower 48 states and Alaska. *Hexalectris* is found in a much narrower range, with a center of diversity in northern Mexico (Luer 1975). As a result, only five of the *Hexalectris* species occur in the United States, and of these species four are limited to parts of Texas (*H. warnockii* Ames & Correll, *H. revoluta* Correll, *H. nitida* L.O. Williams, and *H. grandiflora* (A. Richard & Galeotti) L.O. Williams), Arizona (*H. warnockii*), and New Mexico (*H. nitida*) (Fig. 1). Only *Hexalectris spicata* (Walter) Barnhart ranges widely, occurring along the eastern seaboard as far north as Maryland and West Virginia. The range of two *Hexalectris* species (*H. grandiflora* and *H. revoluta*) is restricted to only two counties in west Texas (Jeff Davis County for *H. grandiflora*, Jeff Davis and Culberson counties for *H. revoluta*; Liggio 1999; Hatch et al. 1990).

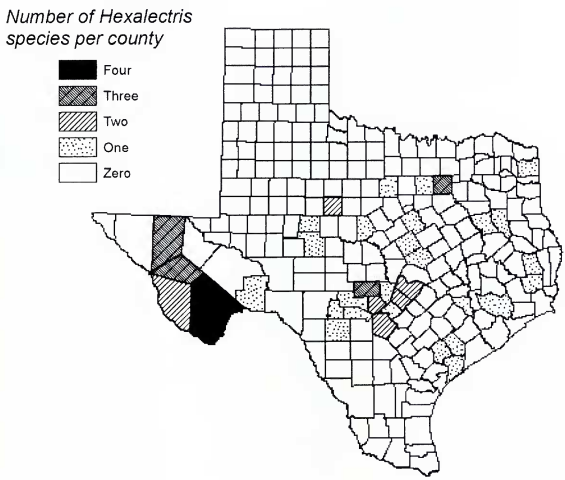

FIG. 1. Distribution map of *Hexalectris* in Texas (based on counties, divided by species, using information from Hatch et al. 1990) Most counties with only one species have either *H. spicata* or *H. nitida*. Most counties with two species have *H. spicata* and *H. nitida*.

In Texas, most of the counties with *Hexalectris* populations are within only three of the state's 11 ecological regions: the Trans-Pecos, the Edwards Plateau, and the Blackland Prairies (Fig. 1; Hatch et al. 1990; Turner et al. 2003). Only *H. spicata* extends beyond these three regions, occurring in all but the High Plains and Rolling Plains of the Texas panhandle. Dallas County (in the Blackland Prairies ecological region) is only one of four counties (Gillespie in the Edwards Plateau, Jeff Davis and Brewster in the Trans-Pecos are the other three) that have three or more species of *Hexalectris*. Dallas County shows a high recorded diversity for Hexalectris, but this is in part related to recently reported range extensions for *H. warnockii* and *H. nitida* (Engel 1987; Mahler 1988), and the new combination *H. spicata* var. *arizonica*, which was described in part based on specimens from the Dallas Nature Center (now Cedar Ridge Preserve) in southwest

Dallas County. However, as most information on *Hexalectris* has appeared only within the last fifty years (Liggio 1999), and relatively few herbarium collections have been made for this genus, *Hexalectris* may perhaps be present over a very large geographic area, and thus be more common than previously thought (Goldman et al. 2002).

In this study we wished to expand the information known about *Hexalectris* abundance and distribution by conducting a detailed census of Cedar Ridge Preserve (CRP) in southwest Dallas County. This is an ideal site for a broad study of *Hexalectris* due to its large area (approximately 256 hectares) and its protected status as both a Dallas County Open Space Preserve and a park within the Dallas Parks and Recreation Department. CRP is also the location of extensive historic study by several orchid hobbyists (V. Engel, D. Williams), long-term plant research and inventory by the Dallas Nature Center (G. Stanford, J. Varnum) and the University of Dallas (M. Brown, A. Collins), as well as the range expansions for *H warnockii* and *H. nitida*, and the discovery of *H. spicata* var. *arizonica* (Catling and Engel 1993). The goals of this study were to 1) compile historic data for *Hexalectris* at Cedar Ridge Preserve, 2) assess the number of *Hexalectris* at the preserve in 2004, 3) determine the ecological characteristics of *Hexalectris* sites, to help provide a more complete description of its habitat, and 4) provide a map of orchid locations at the preserve, to determine whether there are any predictors that may be used to help identify other potential *Hexalectris* sites in Texas.

MATERIALS AND METHODS

All data were collected at Cedar Ridge Preserve, in southwest Dallas County, Texas. CRP is located in one of the few remaining undeveloped areas of the Austin Chalk Escarpment, a geological region of lower Cretaceous limestone that extends northeast from Dallas to the Oklahoma border, and southwest past Waco and Austin into the Edwards Plateau (Dallas Department of Urban Planning 1977)). In Dallas County the escarpment forms a series of steep slopes, with erosion of the bedrock creating a variety of diverse habitats (Kennemer 1987). CRP has been a subject of longtime plant study and monitoring by virtue of its historic role as an environmental center (Greenhills Environmental Center, Dallas Nature Center) and research site (University of Dallas, M. Brown). As a result, we were able to use historic data as well as newly-collected data to create a more complete picture of *Hexalectris* occurrence at the preserve.

Historical data on specific *Hexalectris* locations were obtained by conducting a walk-through of the site (outside of the *Hexalectris* blooming season in November 2003) with Dale Williams, who had significant background knowledge of past orchid records at CRP (Williams 1986). At each site identified by Williams, GPS coordinates were recorded using a Garmin eTrex Legend. Information on dates of specific range extensions for particular species were identi-

fied from published accounts by V. Engel, who had conducted surveys similar to Williams (Engel 1987) and had co-described *H. spicata* var. *arizonica* 11 years earlier (Catling & Engel 1993).

Recent data were obtained through both casual sightings as well as detailed censusing. Casual sightings of *Hexalectris* were recorded during ongoing botanical inventory of the preserve (Brown et al., in prep). During that botanical inventory of approximately 75 hectares of the preserve in 2003 and 2004 we recorded GPS coordinates for any *Hexalectris* observed on study transects. Each *Hexalectris* found during surveys was identified by species, and photographed whenever possible.

On July 23 and 24, 2004 we conducted more extensive surveys to specifically count and map all *Hexalectris* found blooming at the preserve. Survey dates corresponded to dates when *Hexalectris* were found on the preserve in 2003 (S. McCabe, pers. obs.). Survey areas were of two different types: 1) areas where historic data on *Hexalectris* were available or 2) areas that were ecologically similar to places where *Hexalectris* were found in the past. GPS coordinates for these sites were logged and mapped. Censusing was conducted with the help of volunteers from the Master Naturalist Program and other volunteers with significant background knowledge of plants. For most census locations we obtained data from small transects on both the right and left sides of the trail whenever possible, and each transect counted as a sampling point. Transects were 20 m long and approximately 3 m wide. In each transect we counted 1) number of *Hexalectris* colonies, 2) total number of *Hexalectris* stems, and 3) number of *Hexalectris* of each species. Data on plant height were recorded for some *Hexalectris* if they appeared to fall outside the typical height values for the species. In each transect, general ecological data on tree species, canopy, and ground cover were obtained for all sites regardless of whether *Hexalectris* were counted or not. Canopy cover was measured as a percentage value, and ground cover values were estimated as percentage of deciduous leaves, juniper scales/leaves, and bare ground.

Statistical analyses were conducted using Microsoft Excel 2000. During analysis, the actual value of the canopy was used, as well as canopy class (< 20%, 21–40%, 41–60%, 61–80%, >80%). Ground cover was divided into five different groups as a ratio of juniper leaves to deciduous leaves (0/100, 25/75, 50/50, 75/25, and 100/0). Diversity of tree species was calculated for each transect using the Shannon Index, to account for both the diversity and evenness of tree species within the transect. Diversity was compared between sites where orchids were present and sites where orchids were absent. We also compared the percent of trees belonging to the genus *Juniperus* at each sampling point and orchid presence/absence, as well as the percent of trees belonging to genus *Quercus* and orchid presence/absence.

GPS data for all *Hexalectris* sites (both current and historic) were converted

to ArcView shape files using DNR Garmin Version 4.0.28 (Minnesota Department of Natural Resources 2001), and imported into ArcView 8.3. Arc interchange files for soil data were obtained from the Soil Survey Geographic (SSURGO) Database, available from the Soil Survey Laboratory, National Soil Survey Center (Soil Survey Staff 2004). Details on soil series found in Dallas County were obtained from the Soil Survey of Dallas County (Coffee et al. 1980).

RESULTS

Historic and current *Hexalectris* distribution at Cedar Ridge Preserve

The oldest records of *Hexalectris* at Cedar Ridge Preserve are those described in the paper by Engel (1987). In that paper he describes several orchids originally thought to be *Corallorrhiza* in 1981, although their identification was not confirmed until 1986, when they reappeared and were identified as *H. nitida*. A second species, *H. warnockii*, was identified in that same year by Williams (1986). These records remained the last published account of *Hexalectris* at Cedar Ridge Preserve, until the description of *H. spicata* var. *arizonica* in 1991, partly based on specimens collected at the preserve (Catling & Engel 1993).

We were able to identify eight sites at Cedar Ridge Preserve where *Hexalectris* were historically found (Fig. 2, based on D. Williams, pers. comm.), all of which fell on two trails in the southeastern part of the preserve, within an area dominated by mixed hardwoods and the two coniferous species *Juniperus virginiana* (Eastern red cedar) and *Juniperus ashei* (ashe juniper). This matched the common description of *Hexalectris* habitat, variously described as conifer woods on calcareous soils (Diggs et al. 1999), oak litter and decaying juniper scales/leaves (Engel 1987), leaf mold in the shade of cedars or oaks (Luer 1975), and often upon a slight slope (Coleman et al. 2002). In 2003, the preserve's *Hexalectris* were rediscovered during botanical inventories (S. McCabe, pers. obs.), and ultimately we counted a total of 39 *H. warnockii* that year (K. Gempel, J. Varnum, M. Brown, pers. obs.). However, in 2003 *H. spicata* and *H. nitida* were not found/counted anywhere on the preserve.

In 2004 we conducted transect sampling of 89 different locations which were either 1) areas for which historic data on *Hexalectris* were available (N=12) or 2) areas that were ecologically similar to places where *Hexalectris* were found in the past (N=77) (Fig. 2). In 39 (43.8%) of the 89 sites *Hexalectris* was present. In seven out of eight of the sites identified by Williams *Hexalectris* was present, indicating a reasonable degree of accuracy in the historical data obtained outside the *Hexalectris* blooming season. We counted a total of 308 stems in 141 colonies, or an average of 2.2 stems/colony. The breakdown according to species was as follows: 176 stems of *H. nitida* at 25 different locations (57% of all stems, 64% of all locations), 113 stems of *H. warnockii* at 12 different locations (37% of all stems, 31% of all locations), and 15 stems of *H. spicata* at two locations (5% of all stems, 5% of all locations). In addition, we found four stems of

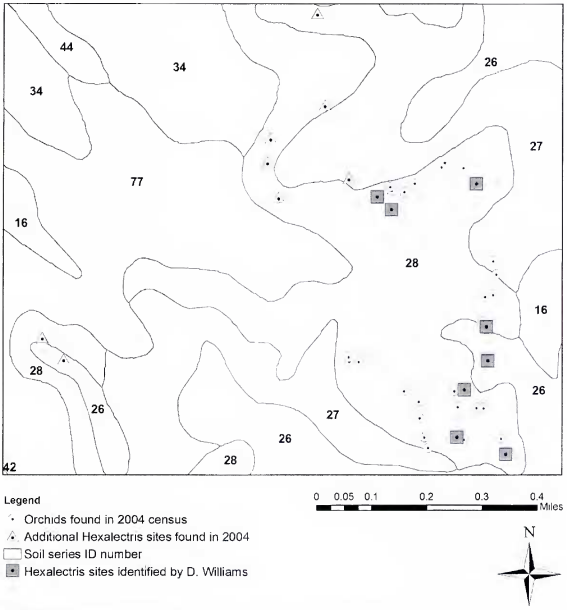

FIG. 2. **Distribution map of *Hexalectris* found at Cedar Ridge Preserve. Soil ID numbers are as follows: 16 (Brackett loam, 3–5% slopes), 26 (Eddy clay loam, 1–3% slopes), 27 (Eddy clay loam, 3–8% slopes), 28 (Eddy-Brackett complex, 8–20% slopes), 34 (Ferris-Heiden complex, 5–12% slopes), 44 (Houston Black clay, 1–3% slopes), 77 (Vertel clay, 5–12% slopes). The category "Additional *Hexalectris* sites found in 2004" refers to areas where *Hexalectris* were found outside of the formal survey on July 23/24 2004.**

Hexalectris in one colony that were atypical, in that they appeared to completely lack any anthocyanin pigment, and thus were pale yellow to light green. Williams had also noted these atypical individuals during his exploration of the preserve. A sample of this type was later tentatively identified as *H. nitida* by researchers at the Botanical Research Institute of Texas (B. Lipscomb, pers. comm.), although further examination of the sample is pending. Due to the large numbers of *Hexalectris* counted in 2004 and limited time, we were unable to

identify plants of the variety *H. spicata arizonica*, but more detailed censusing with trained orchid observers is recommended for inclusion of this type in future censuses. Of the transects studied, only three out of the 39 (8%) had more than one species (2 sites with *H. warnockii* and *H. nitida*, 1 site with *H. nitida* and *H. spicata*).

In the course of sampling we identified several individuals that were taller than the plant heights recorded in the literature. *H. warnockii* is described as ranging up to 30 cm tall (Luer 1975; Diggs et al. 1999), although more recent published accounts have them within a range of 15–40 cm tall (Coleman et al. 2002). In our study we routinely found *H. warnockii* within 30 to 40 cm, with the tallest of this species being 64 cm. For *H. nitida*, published plant heights range from 10–32 cm (Coleman et al. 2002), 15 – 30 cm (Diggs et al. 1999), and up to 30 cm (Luer 1975). Our *H. nitida* were frequently found to be greater than 30 cm tall, with the tallest at 44 cm.

Ecological characteristics of *Hexalectris* sites

Data on canopy cover, ground cover, and tree diversity were obtained from 89 different locations in 2004 *Hexalectris* censusing. To determine whether the presence/absence of orchids is affected by level of canopy cover, canopy was divided into five categories (≤20%, 21–40%, 41–60%, 61–80%, and >80%), which were compared. We found that there was a significant association between canopy cover and orchid presence/absence (χ^2 of association = 13.36, $P < 0.01$, df=4, Fig. 3). Fifty-four percentof the sites with orchids had canopy of between 40 and 60%, and 71% of the sites without orchids had over 60% cover. We found no significant association between the type of ground cover present and orchid presence/absence (χ^2 of association = 5.38, df=3), although all areas on which orchids were found had a ground cover of ≤ 50% juniper leaves.

Diversity of tree species was not significantly different between sites with and without *Hexalectris* (Independent two-tailed $t_{0.05, 85} = 1.054$, n.s.). Sites without *Hexalectris* had a Shannon diversity index of 1.09, compared to 1.17 for sites with *Hexalectris*. Overall, 59% of the trees counted in transects were *Juniperus* spp. (either *J. virginiana* or *J. ashei*), followed by oaks (28% of all trees counted). Sites with and without *Hexalectris* did not significantly differ from one another in the percent of *Juniperus* spp. present (χ^2 of association = 5.43, df=3, n.s.), or in the percent of *Quercus* spp. present (χ^2 of association = 11.42, df=5, n.s.) Only 14% of trees were something other than oak or juniper, and included (in order from highest to lowest number of individuals counted): *Cornus drummondi* (rough-leaf dogwood), *Ilex decidua* (possumhaw), *Fraxinus texensis* (Texas ash), *Viburnum rufidulum* (rusty blackhaw viburnum), and *Rhus* (sumac) spp.

Soil characteristics of *Hexalectris* sites

When soil survey maps were overlaid with maps of *Hexalectris* sites, we were able to show some association between soil type and *Hexalectris* presence (Fig.

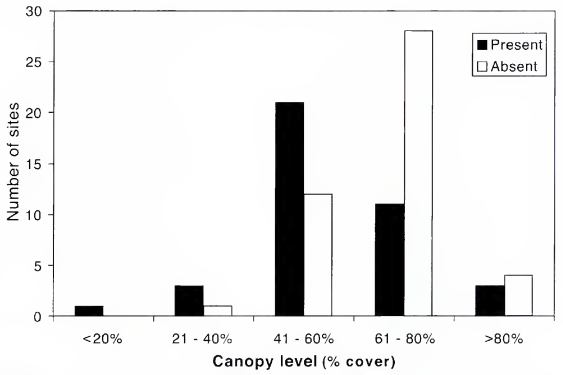

Fig. 3. Relationship between cover class and orchid presence/absence at *Hexalectris* sites

2). Nearly all (93.7% total) of the orchids found were on the Dallas County soil series Eddy-Brackett complex (8–20% slopes). This soil series is classified as a loamy-skeletal, carbonatic, thermic, shallow typic ustorthent (within the entisols), and is often found on strong to moderately sloping hillsides, with a soil depth to approximately 11 inches and a surface layer of grayish brown clay loam 4 inches thick (Coffee et al. 1980). Soils within this complex have rapid runoff, with severe erosion hazard.

Unfortunately, although the data appear to point to an association between soil series and *Hexalectris* presence, interpretation of these data is hampered by the fact that only 16 of the 89 sites examined were something other than the Eddy-Brackett complex (8–20% slopes). To further examine the relationship between soil type and *Hexalectris*, following our initial two-day survey we specifically searched two other areas of the preserve with this soil series, and also mapped datapoints for *Hexalectris* detected during ongoing botanical surveys for other projects at the preserve. Overall, nine additional *H. nitida* were found outside of the 89 areas that we originally surveyed (bringing the total *Hexalectris* count for 2004 to 317). Of these sites, seven (77.7%) were within the Eddy-Brackett complex (8–20% slopes), and the remainder were found on similar soils with less slope. *Hexalectris* found outside of Eddy-Brackett complex (8–20% slopes) were on Eddy clay loam (1–8% slopes) (Coffee et al. 1980).

DISCUSSION

In this study we have been able to provide what is perhaps the largest known count of multiple species of *Hexalectris* orchids at a single research site in the United States. With the initial census from this study, we will be able to follow up our data with future censusing at the preserve and perhaps expansion of the study area into other sites with ecological and soil characteristics similar to those found in this year's census. It is possible that the large number of *Hexalectris* seen this year may be a result of the late spring rains that occurred in Dallas County. In June 2004 Dallas experienced record-breaking rainfall, reaching over 10 inches of rain for the month, or over 250% above the normal June precipitation (Office of the Texas State Climatologist 2004). It is thought that generous rainfall in late spring is necessary for flowering of *Hexalectris* (Engel 1987), although currently there are no published data showing the relationship between rainfall and *Hexalectris* abundance. However, with ongoing censusing of these orchids, we should be able to better elucidate the climatological factors that influence flowering.

Based on the general ecological data collected in this study, we cannot necessarily provide any new information on the plant community with which *Hexalectris* is associated. Oak and juniper are clearly the primary genera that make up both the canopy and ground cover, providing both shelter and a source of decaying organic matter for the fungal symbiont. Yet oak and juniper alone do not necessarily make for good *Hexalectris* habitat. Having a relatively open canopy may also be important, as our study has shown these orchids to be almost completely absent in oak-juniper sites with 60% canopy or greater. As this is not believed to be due to a need for sunlight for photosynthesis (these species do not have chlorophyll and are nonphotosynthetic), cover may influence other factors such as soil or air temperature. Temperature records of microclimate at key sites where *Hexalectris* have been found may be a useful future direction for studies of these species.

The most important result derived from this study is that we were able to predict the occurrence of *Hexalectris* orchids based on soil maps After our initial census efforts, we were able to identify areas on the soil map where a particular soil complex, and consequently the orchids, should occur, and confirm their occurrence through targeted searches. Predictions based on soil type were also corroborated by information from other areas in other parts of Dallas County. *Hexalectris* have frequently been found in Dogwood Canyon, an area approximately 2 kilometers to the southwest of our study area (D. Hurt, pers. comm.). Soil maps reveal that most of the canyon is composed of Eddy-Brackett complex (8–20% slope), with the exception of the lowest levels of the canyon along the creekbed. In addition, long-term observations of areas less than half a kilometer west of the preserve and north of Dogwood Canyon that fall within Cedar Hill State Park show the only recorded orchids to be *Spiranthes* L. C. Rich.

and *Corallorrhiza*, rather than *Hexalectris* (Paul Baldon, CHSP, pers. comm.). Cedar Hill State Park lies mostly on chromustert soils of the Heiden or Vertel complex, which are vertisols, rather than an entisol such as Eddy-Brackett. Finally, we were advised of two small colonies of *Hexalectris* in east Dallas, adjacent to Lower White Rock Creek known as the Scyene overlook (J. Flood, pers. com.) These colonies were located in city parks within an area geologically similar to Austin Chalk Escarpment, and were confirmed to be on Eddy-Brackett complex (8–20% slope). This confirmation helps to solidify the connection between soils and *Hexalectris* incidence in Dallas County.

Based on the information from this study, we have planned to extend this research to other areas with similar soil types. In Dallas County, approximately 1.3% of the land area (3127 hectares) falls within the Eddy-Brackett (8–20%) soil series, and nearly all of these soils are found at 36 locations in the county. With a broader search area, we have the potential to expand the known range of *Hexalectris* within Dallas County, and to protect these areas from expanding development within the county. If the soil-orchid relationship is confirmed in Dallas County, it can potentially be applied to all of Texas. The map of *Hexalectris* distribution in Texas indicates that Dallas County has a high *Hexalectris* diversity compared to most other counties, yet this may be an artifact of a lack of censusing in other areas, or perhaps a limited knowledge of the precise soil and ecological characteristics that this genus requires. With the information from this study, we are confident that the missing pieces of the *Hexalectris* distribution map can be filled, and our knowledge about this genus can be expanded.

ACKNOWLEDGMENTS

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and Wildlife, Cedar Hill State Park) and David Hurt (Dogwood Canyon) provided historic data on *Hexalectris* in other Dallas locations.

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